

# Alberta Biochar Initiative and North American Biochar Working Group

Don Harfield, P.Eng., P.M.P.  
Thermochemical Processing Team Lead  
Vegreville, Alberta, Canada

# Presentation Outline

- **Alberta Innovates**
- **Thermochemical Processing Expertise**
- **AITF Biochar Research**
- **Alberta Biochar Initiative**
- **NA Biochar Working Group**

# Alberta Innovates Family

- **Focuses on strategic Alberta economic sectors:**
  - **Energy:** Oil sands, oil and gas, pipelines, tight oil and fracking
  - **Carbon Conversion, Capture and Storage**
  - **Environmental Monitoring and Management**
  - **Sustainable Resources:** Agriculture and Forestry
  - **Industrial Sensors**
  - **Advanced Materials** and Manufacturing
  - **Health Research** and Technologies



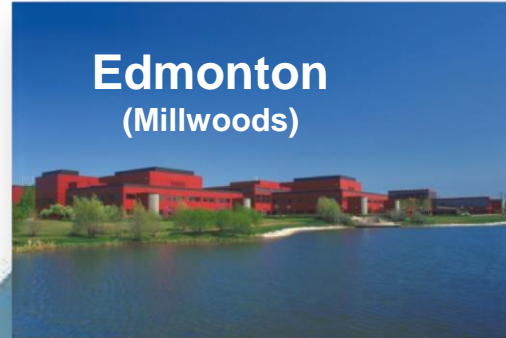
# Alberta Innovates – Technology Futures

- **AITF was established** on January 1, 2010, when four organizations merged (Alberta Ingenuity, Alberta Research Council, iCORE and nanoAlberta).
- **AITF will become a new wholly owned subsidiary** of Alberta Innovates when consolidation of all Alberta Innovates occurs on or about October 1.
- **AITF will have a new name** to reflect the enhanced role in specialized applied research services

# AITF – Current Mandate and Role

- Economic and Social Benefits of Albertans (ESBA)
- Research and Innovation Activities that develop and grow the technology based sector aligned to GoA priorities, including the commercialization of technology and the application of knowledge
- Meet Alberta's Research and Innovation Priorities in agriculture, forestry, energy, the environment, health and other sector areas
- Foster Development and Growth of new and existing industries through research and innovation

# AITF Locations



- 520 world class scientists, engineers, technicians, and business experts
- 1 million sq ft of bench, pilot-scale and demonstration facilities
- 1000+ industry clients per year
- 90+ years of operation
- \$ 75 M fee for service



# AITF Thermochemical Expertise

- **Vegreville Location**

- **Don Harfield, P. Eng., P.M.P.**, Team Lead
- **Ataullah Khan, Ph.D.**, Pyrolysis, Activated Carbon & Catalyst Research Specialist
- **Jin Tak, P. Eng**, Combustion and Chemical Engineer
- **Tim Anderson**, Operations & Lab Supervisor
- **Ami Tymchak**, Alternative Energy Technologist

- **Millwoods Location**

- **Robert Wray, P. Eng.**, Wood Fibre & Torrefaction Specialist
- **Stephanie Trottier, P. Eng**, Gasification Specialist
- **Laura McIlveen, P.Eng.**, Forestry Technical Specialist

- **ABI Collaboration Partner, Lakeland College**

- **Diane Harms**, Executive Director, Vermilion

# AITF Thermochemical Expertise

- **Biochar Production, Slow Pyrolysis**
  - Lab, Bench, Pilot and Demonstration Scale Facilities
  - Biochar Production & Quality Assurance
  - Alberta Biochar Initiative (ABI) Founder
- **Activated Carbons & Functionalized Biochars**
- **Torrefaction**
  - Torrefied Wood Production & Quality Assurance
  - Torrefied Wood Pellets & Binders
- **Wood Combustion**
  - Lab & Pilot Scale Combustion Testing Facilities
  - Demonstration Scale Facilities (Strathcona, Camrose)
  - Client Evaluations (i.e. CHP with Organic Rankine Cycle)



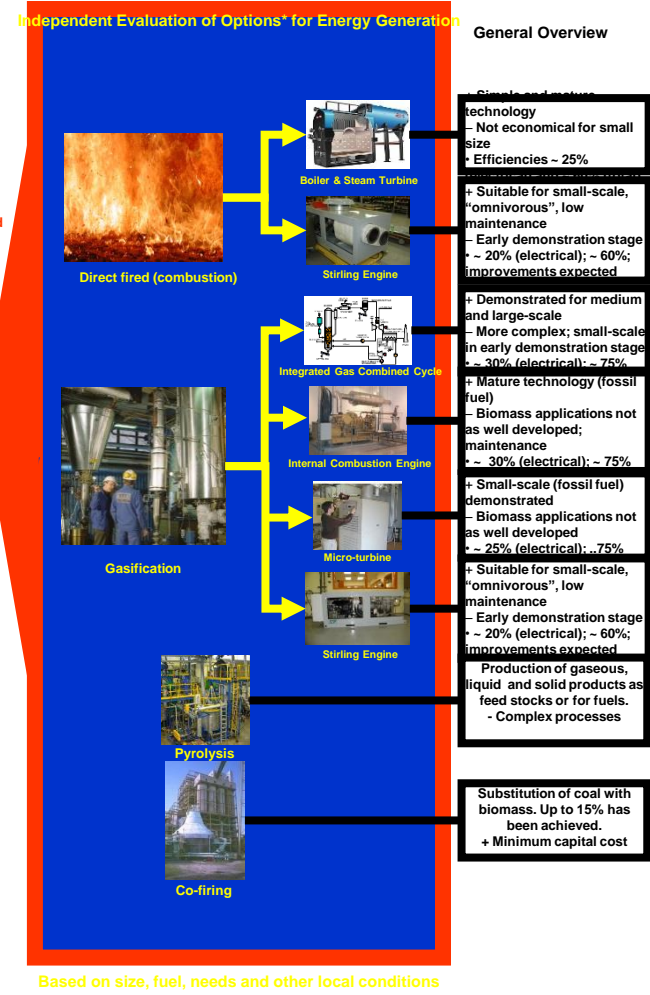
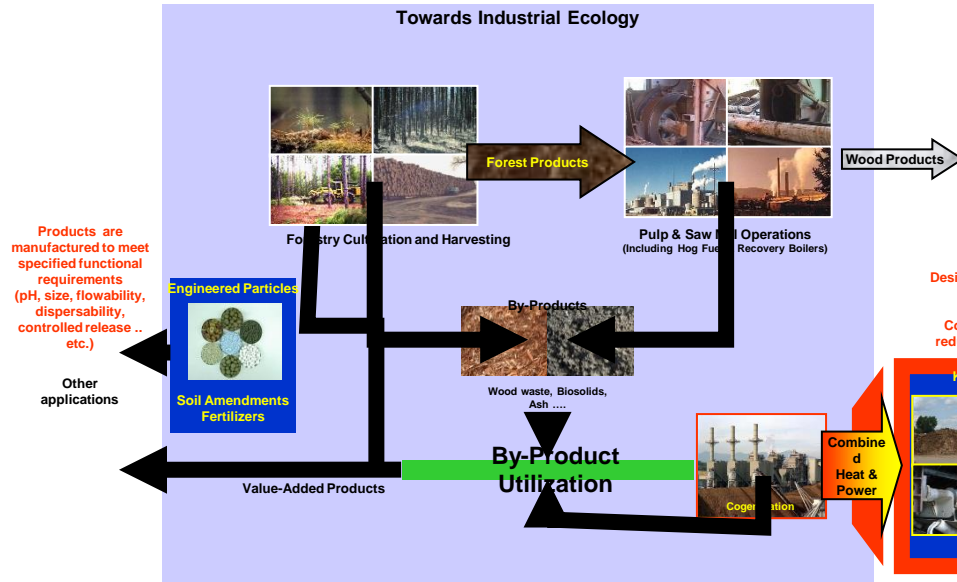
# Related Technical Expertise

- **Gasification**
  - Community Power 35kw Demo Scale Facility
- **Hydrothermal Carbonization**
  - Wet Bio-Coal Conversion
  - Municipal Applications for Wet Biomass or Pathogens
- **Slow Release Fertilizers**
- **Carbon Carrier for Specialty Ag Formulations**
- **Recent Feasibility Studies**
  - Sawmill CHP (Gasification, ORC – 3 MW)
  - Municipal Solid Waste Strategies
  - Biomass Products (Animal Bedding)
- **Performance Validation & Emissions Testing**
- **Process Design & 3<sup>rd</sup> Party Evaluations**

# Particle Engineering Applications to Increased Use of Biomass By-Products

Richard L. Johnson, Carolyn Sturgess and Albert J. Liem  
 Alberta Research Council, P.O. Bag 4000, Vegreville, Alberta T9C 1T4

High Variability in Reported Cost Data  
 Capital Cost: 1,300 – 25,000 \$/kW  
 Energy Generation Cost: 0 – 45 c/ kW-h.  
 Evaluation should be made based on  
 plant size, fuel cost, needs and  
 other site-specific conditions



**Particle Engineering for Product & Feedstock Preparation**

Particle Engineering is the science of combining small particles into larger masses under controlled conditions to manufacture a product with specific composition and functional or performance characteristics.

- Lower transportation cost
- Increased bulk density
- Increased heating value or nutrient density
- Tailor-made composition
- Formulation for soil amendments and fertilizers
- Special fuel feed stock (biomass + scrubbing medium + other fuel)
- Meeting specified handling (flowability) and physical (porosity, dispersability) characteristics and other requirements.

**Expertise and Facilities**

**and Test Products**

**Biomass as Fuel Source**

Energy Source	Cost		Contribution to power cost	
	Purchase	\$/GJ (Fuel)	\$/kW-h @ Eff	%
Electricity*	21 c/kW-h	58.4	21.0	100%
Natural Gas*	\$8.5/GJ	8.5	10.2	30%
Diesel	\$0.50/L	13.1	13.5	35%
Biomass	\$10/tonne	0.5	0.9	20%

\* Actual cost in Vegreville, October 2003

**Economical**

**Life-Cycle GHG emission**

Renewability = Low Life-Cycle Greenhouse Gas Emission

**WANTED: Feasibility, R&D or Demonstration Projects**

Contact: Richard L. Johnson, (780) 632 8252, richardj@arc.ab.ca



# Background Research Into Biochar

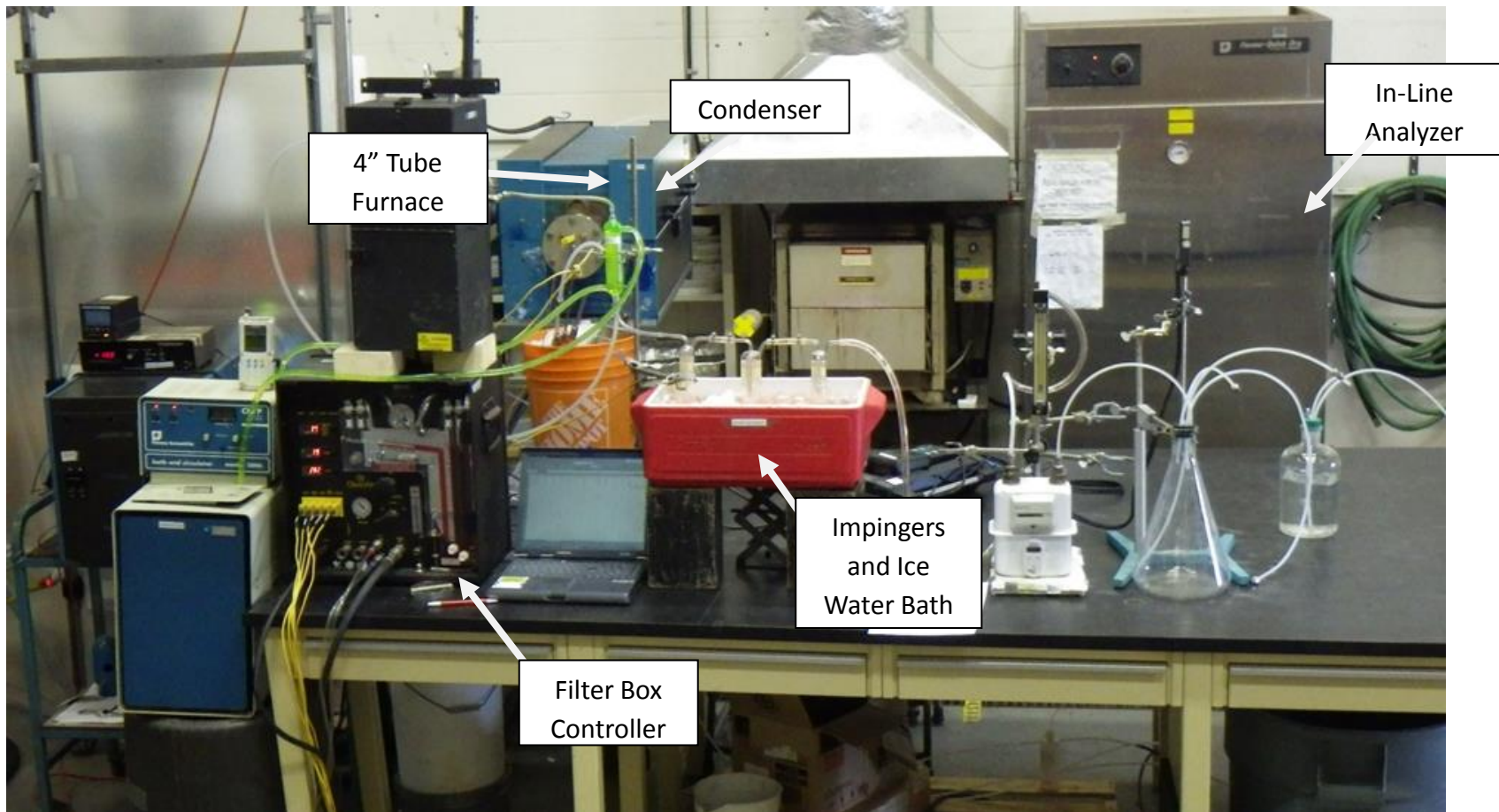
- 2001 – Particle Engineering Group Established
  - R. L. Johnson (Soils Scientist)
- 2003 – Expertise Developed
  - Direct Fired Combustion
  - Gasification
  - Pyrolysis for Fuels and Bio-Coal
  - Co-Firing Substitution of Wood and Bio-Coal
- 2004 – Activated Carbons, MSW Pellet Gasification
- 2005 – Chemically Activated Carbon (Acid)
- 2006 – Steam Activated Carbons (4” Tube Furnace)

# Background Research Into Biochar

- 2007 – Biomass Combustion (Ag Residues & Wood)
- 2008 – Batch Carbonizer & Biochar Products
- 2009 – Biochar Product Development (“Carbon Grow”)
- 2010 – Demonstration Biomass Combustion Facility
- 2011 – Alberta Biochar Initiative (ABI) Commenced
- 2012 – Demonstration Scale Biochar Units Built
- 2013 – Hydroponic Greenhouse Biochar Trials
- 2014 – Oil Sands Tailings Extraction (Funct. Biochar)
- 2015 – ABI Successful Results, Bio-Oils/Phenol Glues, CFIA Biochar Approval

# AITF Bench Scale Pyrolysis System

## Specialty Biochars



# AITF Pilot Scale – Product Development

## Specialty Chars & Pyrolysis Oils



**AITF Continuous Pyrolyzer**

# AITF Pilot Scale – Product Development

## Batch Carbonizer and Steam Activation



**AITF Batch Carbonizer**

# AITF Biochar Production (1/2 Tonne/D)

- Co-founder of the Alberta Biochar Initiative
- Two ABI demonstration scale pyrolysis units located in Vegreville (commissioned in 2013)
- Produced and analyzed a wide variety of biochars produced from varying feedstock materials and pyrolysis conditions
- Analytical lab & established quality standards





# Alberta Biochar Initiative (ABI)



# Alberta Biochar Initiative (ABI)

- 2011 Prior Biochar Study – Market Opportunities
- Pre-Commercial Demonstration Project (3 Yr)
- Initially Federally Funded by WD – \$ 900k
- Partners: AITF, Lakeland College, Industry
- Two Mobile Demo Units (0.5 tonne/day biochar output)
- Carbon Sequestration and GHG Mitigation
- Biochar Network & Partnership Engagement
- Successfully Concluded Funding Period June 2015
- Continuing With Partners to Commercialize Biochar



# ABI Theme 1 – Mobile Production

- Acquired & Commissioned Two Pyrolysis Units
- Hired New Scientist to Lead Pyrolysis
- 7 Feedstock Characterization & Quality Evaluations
- Biochar Hydroponic Media Product Safety
- Demonstration Workshops
- Regulatory Application Process Development



# ABI Theme 2 – Biochar Growth Media

- Produce Biochar from Pulp Mill Sludge
  - Replacement for Perlite & Vermiculite
- Commercial Greenhouse Testing
  - CDC South, Kwantlen
- Microbial Analyses of Biochar & Coir
- Disease Suppression Trials
- Food Safety Testing
- Guidelines for Greenhouse Operators

# ABI Theme 3 – Land Reclamation

- Develop Biochar Based Soil Amendment
- Field Trials for Land Reclamation
  - AITF, Peace River
- Activation of Biochar and Adsorbent Testing
  - Removal of Organic Carbon Extraction from OSTP)



# ABI Theme 4 – Improved Crop Yields

- Production of Biochar from Jerusalem Artichoke, Wheat Straw, Coppice Willow
- Field Trials at Lakeland College (4 Years)
- Evaluate Ameliorative Potential on Soloneztic Soils



# ABI Theme 5 – Networking & Partnerships

- Engagement with 55 Entrepreneurs & Institutions
  - Since Increased to 65 Partners
- 10 Workshops Demonstrating Biochar Units
- Deployment of Biochar Units Offsite
- 37 Technical, Education & Networking Events
  - Edmonton Telus World of Science (Jr. & High School)
- Operational Training of Personnel
- Assisted Partners in Regulatory Applications
  - 2 AENV Code of Practice for Biochar Production
  - 3 CFIA Applications for Biochar as Soil Amendment



# ABI Theme 6 – Carbon Sequestration

- Developed Offset Protocols to Guide Regulations
- Consulted With Alberta Environment and CCEMC
- Issued Report to Develop Alberta GHG Offset System





# CFIA Approval – Biochar!!!

- CFIA considers ‘Biochar’ as a **supplement under the Federal Fertilizer Act** and requires **specific registration** prior to sale/import or prior to environmental release in Canada.
- **Air Terra** with AITF assistance pioneered Biochar Registration with CFIA in Canada
- **Air Terra Biochar** approved December 2015
- **CFIA non-compliance** could result in product detention and prosecution.
- **AITF assisting** with other CFIA applications

# Air Terra Biochar - Specifications

Biochar	Average Result	Air Terra Product Min. Guarantee	Max. Allowable Concentration
<b>Proximate Analyses wt.% dry basis (db)</b>			
Volatile Matter	8.5 %		
Ash	6.7 %	≤ 25 %	
Fixed Carbon	84.8 %	≥ 70 %	IBI Class 1 (> 60 %)*
<b>Ultimate Analyses wt.% (db)</b>			
C	84.56 %		
H	0.68 %		
O	7.84 %		
N	0.22 %		
S	0		
<b>Atomic Ratios</b>			
H/C	0.1		IBI guidelines* require biochar H/C <sub>org</sub> ratio ≤ 0.7
O/C	0.07		Biochar with O/C atomic ratio < 0.2, have an estimated half-life (T <sub>1/2</sub> ) > 1000 year [Carbon Management 2010, 1, 289]
<b>Toxicity Bio-Assay</b>			
Germination Rate	100 %		Radish seed germination rate in biochar relative to quartz sand control
<b>Toxicants</b>			
Polycyclic Aromatic Hydrocarbons - PAHs	1.6 mg/kg		< 20 mg/kg IBI guideline*
Dioxins	Not detected		< 9 ng/kg IBI guideline*
Furans	Not detected		< 9 ng/kg IBI guideline*
Poly Chlorinated Biphenyls - PCBs	Not detected		< 0.5 mg/kg IBI guideline*
Heavy Metals	Within max. allowable conc.		Below CFIA T-4-093 standard threshold

# Biochar: Chicken Soup for the Soil ! \*

<u>ATTRIBUTE</u>	<u>BIOCHAR</u>	<u>CHICKEN SOUP</u>
<b>Improves Health</b>	Improves soil compaction, oxygenation, fertility, water and nutrient retention. Improves soil immunity to disease.	Improves heart health, breathing, digestion, restores immunity, better intestinal flow and spring in your step!
<b>Increases Productivity</b>	Reduces soil erosion and improves crop production from marginal or damaged soils.	Helps restore health and return person to work (and family) sooner and more effectively.
<b>Reduces Need for Chemicals</b>	Reduces need for chemical fertilizers and reduced leaching of nitrogen and phosphorous.	Reduces need for pharmaceuticals and cold (and other) medications
<b>Improves Symbiotic Alignment</b>	Provides high surface area and porous network for microbial growth and enzymes for plant root system.	Re-establishes intestinal microbial balance and harmony for mind and body.
<b>Greenhouse Gas Mitigation</b>	Reduces nitrous oxide emissions by 50 to 80% and methane suppression.	Restabilizes intestinal balance, reduces gas bloating, and noxious emissions
<b>Lasts a Long Time</b>	Recalcitrant stability (longevity) in soil (i.e. Terra Preta).	Helps you live longer and gives you zest for life.
<b>BOTTOM LINE</b>	<b>Helps restore soil, environmentally friendly, and leaves a legacy for doing good! (* Harfield)</b>	<b>Heals body, mind, mood and soul! (Psychology Today)</b>

# Canada's Biomass Innovation

- **Report Issued February 2016** by CCEMC and AI Biosolutions
- **Cleantech Opportunity** for GHG reduction and Economic Prosperity
- **Canada recently signed the Paris Agreement** to reduce GHG emissions
- **Biomass can be used to reduce GHG emissions** at scales from household to heavy industry
- **Opportunities focused primarily** on biomass replacement of fossil fuels such as coal and oil at point sources
- **Draft report for Bio Cleantech in Ontario** issued in May 2016
  - Opportunities for biomass co-generation of heat & electricity
  - Displacement of coal with biomass
  - Landfill gas upgrading
  - Effective fertilizer management and modified crop practices

# Biochar Technical Papers (ABI)

- **Guidelines for Managing Nutrients in Greenhouse Vegetables Grown on Biochar in Alberta**
- **Greenhouse Trials on Biochar as the Growth Media for Cucumber, Tomato and Pepper Hydroponic Vegetable Production**
- **BC Pre-commercial Demonstration of Three Greenhouse Vegetable Crops Grown in Biochar Media Compared with Industry Standard Coco Coir Media**
- ***A Fusarium Oxysporum* Disease Challenge on a Greenhouse Mini-Cucumber Crop to Compare Disease Suppression Effects of Biochar as a Growth Medium with Coco**

# Biochar Technical Papers (ABI)

- **Mapping Biochar Characteristics for Greenhouse Produce Safety Demonstration**
- **Performance & Emissions Testing ABI Biochar Production Units**
- **Greenhouse Trials on the Impacts of Biochar on Plant Pathogen Development and on Diseases Incidences in Greenhouse Cucumber and Tomato Plants**
- **Intent to Develop Alberta Biochar GHG Offset System**

# Higher Value Proposition

**Transform biochar (carbonized biomass) to high value activated carbon replacements**

	Biochar	Activated Carbon
Market Price (d.b.)	\$100 to 500 USD	\$ 1,500 to 5,000 + USD
Product Quality	Standards Being Developed	Well Defined
Market Applications	Being Established, Field Trials	Well Established
Capital Cost	Intensive, Scale Dependent	Intensive, Scale Dependent

# Activated Carbon Market Overview

- **Global AC market valued at \$1.9B in 2012 and expected to reach \$4.2B by 2019**
- **Large number of potential applications**
  - Mercury capture is a major driver for market growth due to new regulations
  - Other potential applications: Flue gas desulfurization, metal removal/recovery, LFG cleanup, capacitive deionization
- **Competitive landscape**
  - 50% market share held by top 3 companies: Cabot Norit, Calgon Carbon, and Evoqua (Siemens)
  - Powdered activated carbon; particle size 1-150  $\mu\text{m}$
  - Granular activated carbon; particle size 0.5-4 mm
  - Extruded activated carbon; particle size 0.8-4 mm



# Example – Mercury Removal

## Mercury Removal from Flue Gas Streams:

Powdered Activated Carbon injection is currently recognized as the “Best Available Control Technology (BACT)” by the EPA for mercury removal in flue gas.



# AITF Functionalized Biochar (FBC)

## Hg Capture Performance

Sorbent	Hg Capture Capacity %	
	AITF-FBC	98.7*
Darco Hg-LH	94.7*	93.5*

\*Equilibrium Temperature  $T_{Hg} = 22\text{ }^{\circ}\text{C}$ ; Ar Carrier; 200 $\mu\text{L}$  injection; 15.6 pg/ $\mu\text{L}$ ;

\*Equilibrium Temperature  $T_{Hg} = 22\text{ }^{\circ}\text{C}$ ; Flue Gas Carrier; 500 $\mu\text{L}$  injection; 15.6 pg/ $\mu\text{L}$ ;  
**Flue Gas Composition:** O<sub>2</sub>: 5%; NO<sub>2</sub>: 300 ppm; SO<sub>2</sub>: 350 ppm; N<sub>2</sub>: Balance;

## Surface Area Measurements

Sorbent	BET SA* m <sup>2</sup> /g
AITF-FBC	517
Darco Hg	660
Darco Hg-LH	335

\*N<sub>2</sub> physisorption

## Abrasion Number Measurement

Sorbent	*Abrasion #
AITF-FBC	77.2
Commercial PACs	70 - 92

\*ASTM D-3802

## AITF-FBC Leachate Analyses – TCLP Testing\*

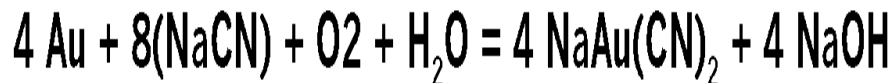
Extraction/ Leaching Solution pH	Leachate Hg Conc. (ppb)	TCLP Regulated Level for Hg (D-008) in Leachate (ppb)	TCLP Test Result
3	21.3	200	Pass
7	2.02	200	Pass
11	3.05	200	Pass

\*cold vapor atomic fluorescence spectrometer (CVAFS); \*Spent FBC Hg conc.: 97.1 ppm;

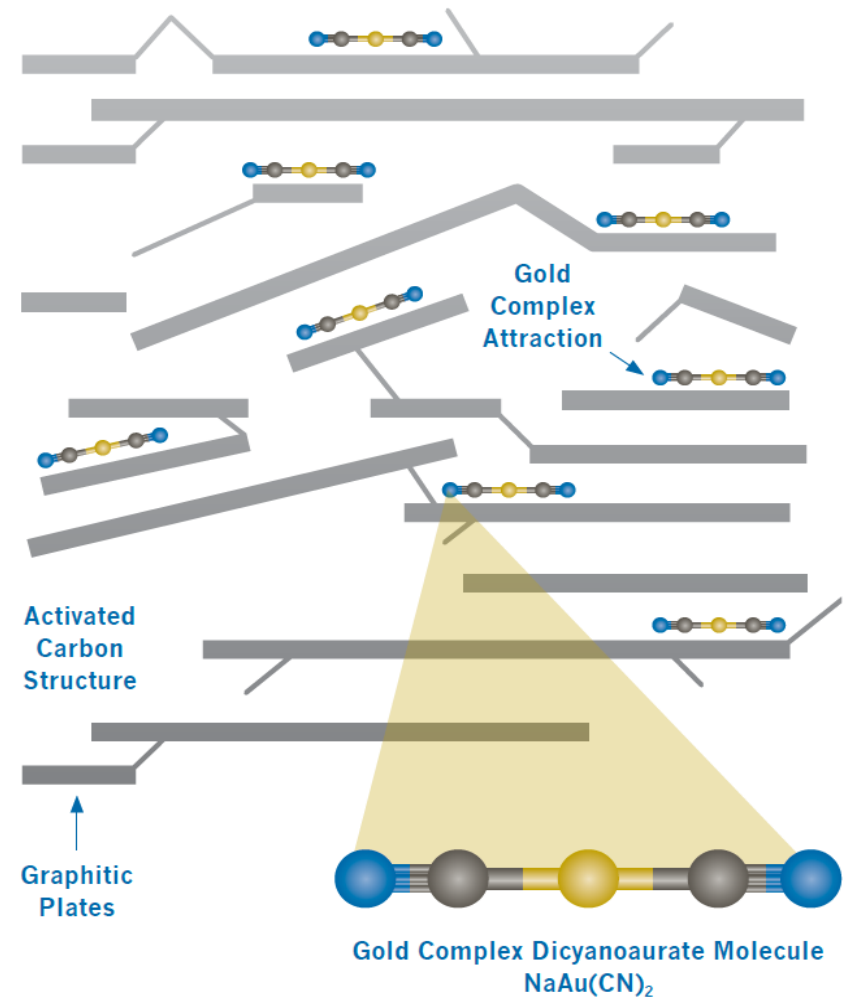
# Example: Enhanced Gold Recovery

## Cyanidation:

Gold in crushed ore reacts with sodium cyanide to form a gold-cyanide complex, which is attracted to the activated carbon, allowing for easier and cheaper processing.



## ADSORPTION OF GOLD CYANIDE COMPLEX



# Environmental & Other Applications

- **Toxic Organics from Oil Sands Processed Water**
  - Development of a cost-effective biochar-based adsorbent for toxic organic removal from tailings waters
- **Carbon Based Fertilizers (Slow Release)**
  - Ammonium Sulfate & Ammonium Phosphate
- **“Green” Phenolic Glues**
  - Cost savings of 40% compared to Petroleum Based Phenolic Glues



# **North American Biochar Working Group**

# North American Biochar Working Group

- **Introductory Meeting** at USBI 2016 Hosted by:
  - USBI, Alberta Biochar Initiative & Mexican Biochar Initiative
- **Purpose:** Collaboration Working Group to Advance Biochar Markets and Production in North America
- **Invitations** to all USBI 2016 Attendees
  - Representation from US, Canada & Mexico
  - Approx . 50 Attended Meeting on Monday Afternoon
- **Intended Topics Included:**
  - End User Markets and Applications
  - Production Successes and Learnings
  - Product Applications (Biochar & Activated Carbons)
  - Regulatory Considerations

# North American Biochar Working Group

- **Key Discussion Points:**

- Market Demand is the Driver to Grow Biochar Industry
- Quality & Consistency is Paramount
- Need for Definitions (Standards), Regulations and Policies
- Strong Interest in Biochar Industry Association with NA Perspective
- Strong Interest in Establishing NA Biochar Working Group

- **Outcomes**

- Issue Survey to Working Group Attendees
- Obtain Feedback on Priorities and Commitment for Working Group and or Industry Association
- Develop and Issue Draft Motions for IBI and USBI
- Obtain Input from IBI and USBI on Survey Results and Draft Motions

# Opportunities to Contribute

## **Benefits to Contributors!**

**The More You Put Into It – The Greater the Reward!**

## **Opportunities to Contribute!**

### **Main Contacts:**

- **Tom Miles – Tel (503) 292-0107**
- **Don Harfield – Tel (780) 632-8271**
- **Ramon Bacre – Tel (231) 313-5117**



# Alberta Biochar Initiative and NA Biochar Working Group Presentation



## Thank You!

**Don Harfield, P.Eng., P.M.P.**

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**Presentation to USBI 2016**  
Corvallis, Oregon August 23, 2016